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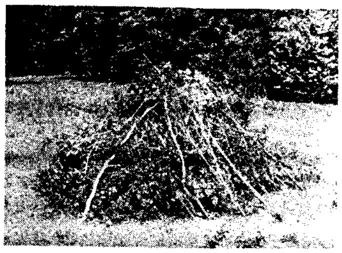

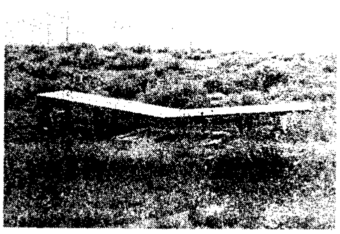

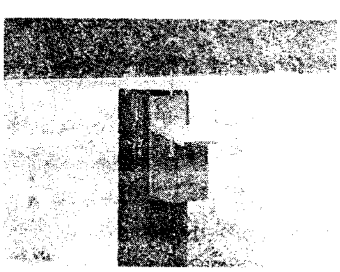

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SONGBIRD NEST BOXES

Section 5.1.8, US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL

by

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This report on songbird nest boxes is provided as Section 5.1.8 of the US Army Corps of Engineers Wildlife Resources Management Manual. It was prepared as a guide to assist project biologists in developing and implementing nest box programs for nongame birds. Topics covered include wildlife value, management objectives, design, construction, installation, placement, maintenance, evaluation, personnel and costs, and cautions and limitations.

Loss of natural tree cavities has limited the availability of suitable nest sites for many wildlife species in North America. Nest box programs have been effective in restoring and maintaining populations of cavity-nesting songbirds, the most notable example being the eastern bluebird (*Sialia sialis*). A variety of nest box designs are presented in this report, but the bluebird box is emphasized because its dimensions can be readily adapted to other cavity nesters. Detailed specifications are given for this standard box and for

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specialized boxes such as purple martin (*Progne subis*) houses. Appropriate management objectives are discussed, and guidelines are provided for the construction, installation, and location of nest boxes with emphasis on placement in suitable habitat. Monitoring and maintenance procedures are described, and the criteria for evaluating box use and nest success are discussed.

PREFACE

This work was sponsored by the Department of Defense (DOD) military branches under the DOD Natural Resources Program. Technical Monitors for the study were representatives of the Fish and Wildlife Committee of the Defense Natural Resources Group, DOD. The report serves as a section of the US Army Corps of Engineers Wildlife Resources Management Manual, as developed by the Headquarters, US Army Corps of Engineers, under the Environmental Impact Research Program.

This report was prepared by Dr. Wilma A. Mitchell, Wetlands and Terrestrial Habitat Group (WTHG), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Mr. Chester O. Martin, Team Leader, Wildlife Resources Team, WTHG, was principal investigator for the work unit. Review and comments were provided by Mr. Martin, Mr. James W. Teaford, Dr. Thomas H. Roberts, and Dr. James S. Wakeley, WTHG.

The report was prepared under the general supervision of Dr. Hanley K. Smith, Chief, WTHG, EL; Dr. Conrad J. Kirby, Chief, Environmental Resources Division, EL; and Dr. John Harrison, Chief, EL. The report was edited by Ms. Jessica S. Ruff of the WES Information Products Division (IPD). Drawings were prepared by Mr. John R. Harris, Scientific Illustrations Section, IPD, under the supervision of Mr. Aubrey W. Stephens, Jr.

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NOTE TO READER

This report is designated as Section 5.1.8 in Chapter 5 -- MANAGEMENT PRACTICES AND TECHNIQUES, Part 5.1 -- NESTING AND ROOSTING STRUCTURES, of the US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL. Each section of the manual is published as a separate Technical Report but is designed for use as a unit of the manual. For best retrieval, this report should be filed according to section number within Chapter 5.

SONGBIRD NEST BOXES

Section 5.1.8, US ARMY CORPS OF ENGINEERS
WILDLIFE RESOURCES MANAGEMENT MANUAL

A decline in mature forests in North America has resulted in the loss of natural tree cavities, which has severely limited the availability of nest sites for many species. The provision of nest boxes to supplement natural cavities has become a widely used management technique. Nest box programs have played an important role in the restoration of species such as the eastern bluebird (Fig. 1), for which the loss of nesting habitat has been a major factor in population declines.

Use of nest boxes as a management tool for cavity-nesting songbirds is the emphasis of this report. However, incidental use of songbird nest boxes by other wildlife species is addressed where appropriate. A variety of designs are presented, and guidelines for construction, installation, and placement of boxes are discussed in detail. Nesting structures used in the

Figure 1. Eastern bluebird using a nest box, commonly referred to as the bluebird box

management of raptors and waterfowl are described in other sections of the manual.

WILDLIFE USE

Songbird nest boxes are used by a variety of cavity-nesting birds and are frequently occupied by small mammals, reptiles, and amphibians (Table 1). At least 44 species of birds in North America have been reported to nest in boxes. The majority are cavity-nesting birds, those species that require a cavity for nesting rather than an open nest. Primary cavity nesters, chiefly woodpeckers, build their nests in holes that they excavate in the soft wood of decaying trees, whereas secondary cavity nesters, such as bluebirds and wrens, use holes that have been excavated and previously used by primary cavity nesters. Although woodpeckers occasionally nest in boxes, the excavation process appears to be an essential nesting requirement for most species in

Table 1. Wildlife species known to use boxes designed for cavity-nesting birds*,**

<u>SONGBIRDS</u>

American robin (*Turdus migratorius*) - shelves only

Bluebirds
- Eastern bluebird (*Sialia sialis*)
- Mountain bluebird (*S. currucoides*)
- Western bluebird (*S. mexicana*)

Brown creeper (*Certhia americana*) - infrequent use

Chickadees and titmice (*Parus* spp.)
- Black-capped chickadee (*P. atricapillus*)
- Carolina chickadee (*P. carolinensis*)
- Mountain chickadee (*P. gambeli*)
- Tufted titmouse (*P. bicolor*)
- (Other species of chickadees and titmice will probably use nest boxes if provided.)

European starling (*Sturnus vulgaris*)

Flycatchers
- Ash-throated flycatcher (*Myiarchus cinerascens*)
- Eastern phoebe (*Sayornis phoebe*) - shelves only
- Great crested flycatcher (*M. crinitus*)

House finch (*Carpodacus mexicanus*)

House sparrow (*Passer domesticus*)

Nuthatches (*Sitta* spp.)
- Brown-headed nuthatch (*S. pusilla*)
- Pygmy nuthatch (*S. pygmaea*)
- Red-breasted nuthatch (*S. canadensis*)
- White-breasted nuthatch (*S. carolinensis*)

Prothonotary warbler (*Protonotaria citrea*)

Swallows
- Barn swallow (*Hirundo rustica*) - shelves only
- Purple martin (*Progne subis*)
- Tree swallow (*Tachycineta bicolor*)
- Violet-green swallow (*T. thalassina*)

Woodpeckers
- Downy woodpecker (*Picoides pubescens*)
- Golden-fronted woodpecker (*Melanerpes aurifrons*)
- Hairy woodpecker (*P. villosus*)
- Lewis' woodpecker (*M. lewis*)
- Northern flicker (*Colaptes auratus*)

(Continued)

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* Table compiled from major references cited in the text.
** Species listed alphabetically within major groupings.

Table 1 (Continued)

SONGBIRDS (Continued)

Woodpeckers (Continued)
- Pileated woodpecker (*Dryocopus pileatus*)
- Red-bellied woodpecker (*Melanerpes carolinus*)
- Red-headed woodpecker (*M. erythrocephalus*)
- Yellow-bellied sapsucker (*Sphyrapicus varius*)
- (Other species of woodpeckers will occasionally use boxes.)

Wrens
- Bewick's wren (*Thryomanes bewickii*)
- Carolina wren (*Thryothorus ludovicianus*)
- House wren (*Troglodytes aedon*)

RAPTORS - primarily use specially designed larger boxes

American kestrel (*Falco sparverius*)

Owls
- Barred owl (*Strix varia*)
- Common barn-owl (*Tyto alba*)
- Eastern screech-owl (*Otus asio*)
- Flammulated owl (*O. flammeolus*)
- Northern saw-whet owl (*Aegolius acadicus*)
- Whiskered screech-owl (*O. trichopsis*)

WATERFOWL - primarily use specially designed larger boxes

- Black-bellied whistling-duck (*Dendrocygna autumnalis*)
- Common goldeneye (*Bucephala clangula*)
- Common merganser (*Mergus merganser*)
- Hooded merganser (*Lophodytes cucullatus*)
- Wood duck (*Aix sponsa*)

MAMMALS

Bats - several species will use songbird nest boxes

Mice
- Deer mouse (*Peromyscus maniculatus*)
- Eastern woodrat (*Neotoma floridana*)
- Golden mouse (*Ochrotomys nuttalli*)
- White-footed mouse (*P. leucopus*)

Ringtail (*Bassariscus astutus*) - large boxes only

Squirrels
- Arizona gray squirrel (*Sciurus arizonensis*)
- Eastern gray squirrel (*S. carolinensis*)
- Fox squirrel (*S. niger*)
- Red squirrel (*Tamiasciurus hudsonicus*)

(Continued)

Table 1 (Concluded)

MAMMALS (Continued)
Squirrels (Continued)
Northern flying squirrel (*Glaucomys sabrinus*)
Southern flying squirrel (*G. volans*)
Virginia opossum (*Didelphis virginiana*) - large boxes only
AMPHIBIANS AND REPTILES
Amphibians
Gray treefrog (*Hyla versicolor*)
Green treefrog (*H. cinerea*)
Squirrel treefrog (*H. squirella*)
Lizards
Green anole (*Anolis carolinensis*)
Skinks (*Eumeces* spp.)
Broadhead skink (*E. laticeps*)
Five-lined skink (*E. fasciatus*)
Southeastern five-lined skink (*E. inexpectatus*)
Snakes
Rat snake (*Elaphe obsoleta*)
Black rat snake (*E. o. obsoleta*)
Texas rat snake (*E. o. lindheimeri*)

this group of birds (Thomas et al. 1979). Therefore, nest box management is conducted primarily for secondary cavity nesters.

Some species use boxes as shelter or roosting sites. Birds of eastern forests known to roost in nest boxes include the northern flicker, red-bellied woodpecker (McComb and Noble 1981b), and eastern screech-owl (VanCamp and Henny 1975, Fowler and Dimmick 1983). Resident songbird species such as the Carolina chickadee, Bewick's wren, and tufted titmouse may also use boxes as winter roosts (Thomas 1946).

Rodents such as the deer mouse (Miller 1970), white-footed mouse (Webster and Uhler 1964), and southern flying squirrel (Goertz et al. 1975) will also nest in songbird boxes. Mammals that use songbird nest boxes as temporary shelter include the deer mouse (Kibler 1969), ringtail (Hakes 1983), eastern gray squirrel (Fowler and Dimmick 1983), red squirrel (Kibler 1969), and flying squirrels (Fowler and Dimmick 1983, Obee 1984). Reptiles and amphibians have also been found using boxes for shelter (McComb and Noble 1981a).

In some studies, cavity-nesting species have shown a preference for boxes over natural cavities (Bellrose et al. 1964, Strange et al. 1971, Pinkowski 1976, McComb and Noble 1981b). For example, in 3 forest habitats in Louisiana, up to 29.3% of boxes were used by vertebrates, whereas only 12.5% of cavities were occupied (McComb and Noble 1981b). Herpetofauna such as treefrogs and skinks were also found in boxes more often than in natural cavities (McComb and Noble 1981a).

MANAGEMENT OBJECTIVES

A songbird nest box program may have one or more objectives and may be applied to (1) reestablish a local or regional population that has declined or been eliminated through habitat loss; (2) attract birds to an area where there is adequate foraging habitat to support a population, but nesting sites are limited or unavailable; (3) maintain a remnant population of woodpeckers during forest regeneration and snag development; and (4) increase public enjoyment and appreciation of the wildlife resource, especially along trails or as part of an urban wildlife management program.

A nest box program may be developed for a single cavity-nesting species, or it may include several species. It will be more successful if boxes are designed for target species, with dimensions appropriate to the size of the species and to the exclusion of predators or competitors. Extra boxes should be provided so that nests of nontarget but desirable wildlife species can be accommodated. For example, box use by flying squirrels should be acceptable on a bluebird trail with numerous boxes, especially in an area where natural cavities are scarce. Boxes left up during winter may be used by other than the target species for shelter or roosting (McComb and Noble 1981b). Fowler and Dimmick (1983) found that screech-owls nested in boxes in eastern Tennessee during the spring, and gray squirrels used many of the same boxes for shelter in winter. Placing nest boxes for multiple species could be a particularly effective use of boxes in spatially limited areas such as urban settings.

Management objectives should be thoroughly evaluated before implementing a nest box program. For example, it would be unrealistic to expect to establish a population of primary cavity nesters through a nest box program alone (Mannan et al. 1980, Peterson and Grubb 1983). Froke (1983) maintained that nest boxes do not effectively mitigate for the loss of natural nest sites and that replication of avian communities should not be expected through nest box use in the absence of natural habitat. The maintenance of a nest box program does not eliminate the need to preserve and manage wildlife habitat (Henderson 1984). Therefore, nest boxes should not be considered as a replacement for natural cavities but rather as a management tool to enhance existing habitat chiefly for secondary cavity nesters.

DESIGN AND CONSTRUCTION

Nest boxes simulate natural cavities and should be constructed specifically for target species (Henderson 1984) because proper box dimensions often determine nest success (Yoakum et al. 1980). Designs for a variety of nest boxes have been published (Sawyer 1955, Peterson 1963, Kalmbach and McAtee 1969, Schutz 1970, Zeleny 1976, Boone 1979, McNeil 1979, Gary and Morris 1980, Durant 1981, Henderson 1984). Specifications for several types of songbird nest boxes are presented in this report. However, the emphasis is on a basic design that can be easily modified to accommodate most cavity nesters. In the past decade, this box has been successfully used in efforts to restore the eastern bluebird to its former range, and it is generally known as the bluebird box (Fig. 1).

Construction details for a top-opening and side-opening bluebird nest box are shown in Figures 2 and 3; the dimensions needed for adapting this box to other cavity-nesting species are presented in Table 2. The exact box size is usually not critical as long as it is approximately the size recommended for the target species (University of Tennessee, undated). Builders tend to overestimate the cubic capacity needed for a box because the nesting bird occupies a much smaller space than its length would seem to indicate (Sawyer 1955). Boxes with minimum dimensions are more economical to construct and less conspicuous in the field. Except for box dimensions, the information presented below applies generally to all nest box designs.

Design Elements

Entrance. The size of the entrance hole is the most important dimension in nest box design (Zeleny 1978). The entry hole should be no larger than is needed to accommodate target species and restrict use by undesirable competitors such as starlings and house sparrows. House sparrows can enter a hole

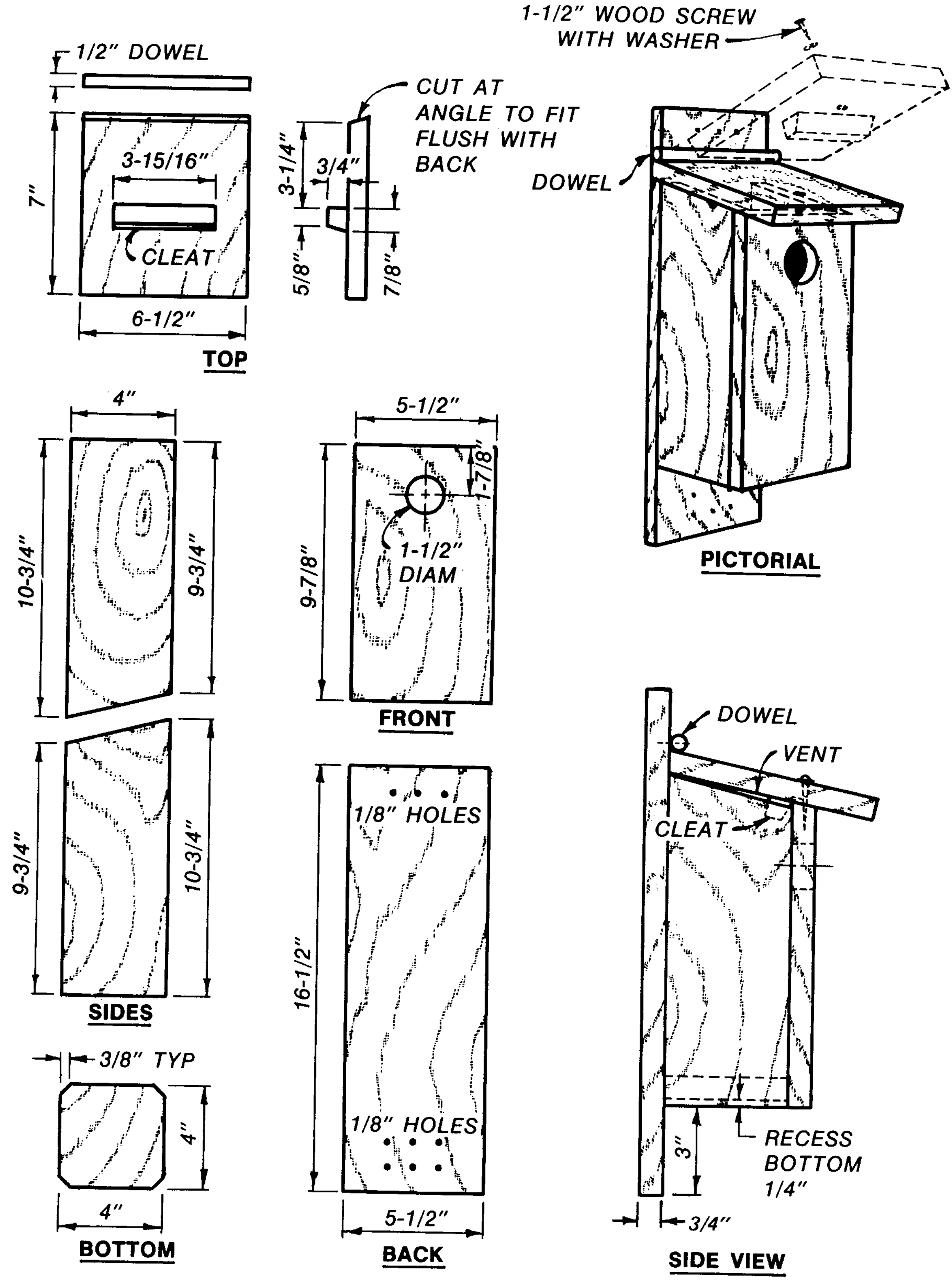


Figure 2. Construction details for a top-opening songbird nest box (after guidelines provided by the North American Bluebird Society)

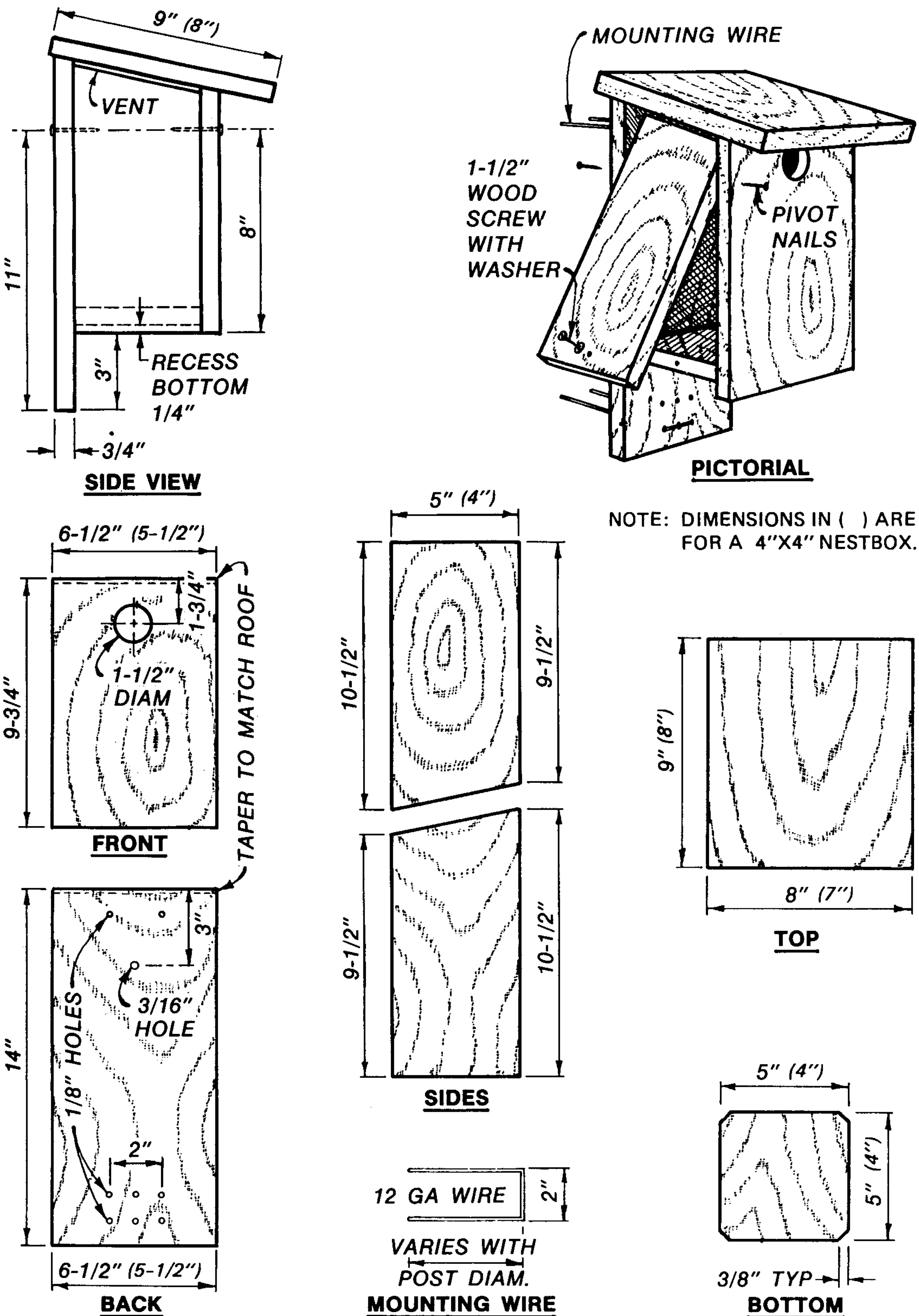


Figure 3. Construction details for a side-opening songbird nest box (after Zeleny 1976)

Table 2. Nest box dimensions and heights for box placement*

Species	Box Floor (in.)	Box Depth (in.)	Entrance Height** (in.)	Entrance Diameter (in.)	Box Height (ft)
American robin†	7 × 8	8	--	--	6-15
Eastern bluebird	4 × 4	8-12	6-10	1-1/2	4- 6
Mountain bluebird	5 × 5	8-12	6-10	1-1/2	4- 6
Western bluebird	4 × 4	8-12	6-10	1-1/2	4- 6
Chickadees	4 × 4	8-10	6-8	1-1/8	4-15
Titmice	4 × 4	8-10	6-8	1-1/4	5-15
Ash-throated flycatcher	6 × 6	8-10	6-8	1-1/2	5-15
Great crested flycatcher	6 × 6	8-10	6-8	1-3/4	5-15
Phoebes†	6 × 6	6	--	--	8-12
Brown-headed nuthatch	4 × 4	8-10	6-8	1-1/4	5-15
Pygmy nuthatch	4 × 4	8-10	6-8	1-1/4	5-15
Red-breasted nuthatch	4 × 4	8-10	6-8	1-1/4	5-15
White-breasted nuthatch	4 × 4	8-10	6-8	1-3/8	5-15
Prothonotary warbler	5 × 5	6	4-5	1-3/8	4- 8
Barn swallow†	6 × 6	6	--	--	8-12
Purple martin	6 × 6	6	1-2	2-1/2	6-20
Tree swallow	5 × 5	6-8	4-6	1-1/2	5-15
Violet-green swallow	5 × 5	6-8	4-6	1-1/2	5-15
Downy woodpecker	4 × 4	8-10	6-8	1-1/4	5-15
Golden-fronted woodpecker	6 × 6	12-15	9-12	2	10-20
Hairy woodpecker	6 × 6	12-15	9-12	1-1/2	8-20
Lewis' woodpecker	7 × 7	16-18	14-16	2-1/2	12-20
Northern flicker	7 × 7	16-18	14-16	2-1/2	6-20
Pileated woodpecker	8 × 8	16-24	12-20	3 × 4	15-25
Red-headed woodpecker	6 × 6	12-15	9-12	2	10-20
Yellow-bellied sapsucker	6 × 6	12-15	9-12	1-1/2	10-20
Bewick's wren	4 × 4	6-8	4-6	1-1/4	5-10
Carolina wren	4 × 4	6-8	4-6	1-1/2	5-10
House wren	4 × 4	6-8	4-6	1-1/4	5-10

* Table compiled from Kalmbach and McAtee 1969, Roberts 1972, McNeil 1979, Gary and Morris 1980, Yoakum et al. 1980, Wakeley and Wakeley 1983, Henderson 1984, and Obee 1984.

** Height of entrance hole above nest box floor.

† Use nesting shelf, which has open front.

greater than 1-3/8 in. in diameter, and starlings can enter an opening larger than 1-1/2 in. (Gary and Morris 1980). To exclude starlings, it is critical that the entrance hole be limited to the 1-1/2-in. diameter recommended for bluebirds and similar-sized species (Zeleny 1976).

The entrance hole should be round and located near the top of the front panel; if placed near floor level, entry holes permit drafts and subject nestlings to lowered nest temperatures (Sawyer 1955). The bottom of the entrance should be at least 6 in. above the floor for bluebirds and most other species (Zeleny 1976). Boxes that are too shallow allow predators to reach inside and destroy nest contents even though they cannot fully enter the boxes (Kilham 1971).

Floor. There are two schools of thought on floor dimensions for some species, especially bluebirds. Some authors suggest 4- × 4-in. floors, whereas others recommend the 5- × 5-in. floor. The larger boxes are acceptable to all bluebird species and provide ample room for large broods. However, Zeleny (1976) pointed out that the smaller boxes closely approximate the size of natural nest cavities excavated by downy woodpeckers and most commonly used by bluebirds. Boxes with smaller floors are also lighter and thus easier to mount, are less expensive to build, provide sufficient room under most circumstances, and tend to discourage house sparrows. The 5- × 5-in. floor may be advantageous to the mountain bluebird, however, as it is larger than the eastern and western bluebirds.

Sides. The sides of the nest box should enclose the floor, which is recessed 1/4 in. from the bottom of the box sides (Fig. 3) (Henderson 1984). This will prevent rain from seeping into the nest through cracks between the sides and floor and will delay deterioration caused by moisture retention.

Roof. The roof should have sufficient pitch to shed water readily and should overhang the front of the box by approximately 3 in. (Gary and Morris 1980). This aspect of design affords protection from wind-driven rain and minimizes predation by cats and other mammals that can reach into the box from above (Henderson 1984).

Vent and drainage holes. Openings for ventilation protect against overheating, and a few well-placed drainage holes allow water to escape. To provide adequate ventilation, narrow spaces may be left between the roof and sides, or two 1/4-in. holes may be drilled in each side of the box just below the roof (Davison 1967). Several drainage holes may be drilled in the bottom, but drainage is better accomplished by cutting away approximately 3/8 in. from each corner of the floor as shown in Figure 3 (Zeleny 1976).

Interior. The front panel should contain a means to assist young birds in leaving the nest. Cleats (strips of wood nailed horizontally) or screen wire may be attached to the inside wall just below the entrance hole to provide a toehold for fledglings (Davison 1967). The same effect can be provided by roughening or grooving the lumber with a file, saw, or wood chisel (Kalmbach and McAtee 1969).

Perch. A perch should not be placed on nest boxes (Zeleny 1976, Henderson 1984, Obee 1984). It is unnecessary for most target species and is preferred only by house sparrows and starlings. A perch provides a convenient waiting site for house sparrows trying to take possession of boxes and for starlings attempting to prey on nestlings. Drinkwater (1953) observed a kestrel using a perch that allowed it to reach into a box and extract the nestlings.

Box opening. It is essential to provide a top or side that can be opened to facilitate inspection and cleaning of nest boxes. The top-opening design is preferred for boxes subject to frequent monitoring, as nesting birds are less likely to be disturbed; nestlings can also escape from the side-opening box and greatly reduce their chances for survival (Zeleny 1976). However, the side-opening box is easier to clean and is recommended for untidy species such as tree swallows (Grant 1988).

Although the box should be convenient to open for observation, one too easily opened may invite vandalism or disturbance of nesting birds by curious passersby. A satisfactory compromise is a box with a top or side that can be held shut by a single screw or nut; however, if boxes are on private property or an area where vandalism is unlikely, a wing nut, latch, or twist catch may be more convenient.

Materials

Durable and weather-resistant materials should always be selected, as a well-constructed nest box should last for 10 to 15 years (Henderson 1984). Wood has long been the most satisfactory and most commonly used material for nest box construction (Zeleny 1976, Henderson 1984). Birds are habituated to wood, and it produces natural-looking boxes that are durable, visually attractive, and relatively easy to build. Wood is also a good insulator, resistant to weather extremes, and ages gracefully over time (Sawyer 1955). Metal should not be used because it overheats in the sun (Kalmbach and McAtee 1969).

Lumber. The most durable woods for nest box construction are bald-cypress, redcedar, and redwood. Although less durable, pine is easier to work and much less expensive (Zeleny 1976). Exterior grade plywood, called T-11, is also an excellent construction material that weathers well and is often used for siding on homes (McNeil 1979). Because it does not warp, this plywood is recommended for the roof (top board) even when other materials are used for the rest of the box (Mississippi State University 1981). Softwood such as pine is a good material for constructing smaller nest boxes, but cedar, cypress, and redwood are better for the larger ones (Henderson 1984).

Boxes may be constructed of old or new lumber; a box made of old lumber is less noticeable and therefore less subject to human interference (Krug 1941). Either rough or planed lumber may be used (Zeleny 1976). Sawyer (1955) recommended that new lumber be rough to blend with surroundings; however, planed lumber is more readily available and usually easier to secure for a large project. Lumber treated with wood preservative should be avoided, as the preservative may be harmful to nesting birds. The Environmental Protection Agency has designated some of the commonly used preservatives as restricted-use pesticides, which demand extreme care in use and application; these include pentachlorophenol (penta), creosote, and inorganic arsenicals such as copper-chromated arsenate (CCA), ammonia-chromated arsenate (ACA), and ammonia-chromated zinc arsenate (ACZA) (Martin 1986).

To provide adequate insulation, lumber should be at least 3/4 in. thick, a thickness that is also easy to work (Henderson 1984). If slab wood is used, board thickness may vary from 3/8 in. at the edge to 2 in. at the thickest part (Sawyer 1955). The width and depth of planed lumber are smaller than the standard description, and boards are from 1/2 to 3/4 in. less than the nominal widths (Zeleny 1976). For example, a 1- × 6-in. board is only 3/4 × 5-1/2 in., and a 2- × 4-in. board is 1-1/2 × 3-1/2 in. Therefore, planed lumber should be checked for its actual size before purchasing.

Hardware. Galvanized nails are recommended for the assembly of nest boxes (Zeleny 1976, McNeil 1979). Siding nails of 12-1/2 or 14 gauge and 1-3/4-in. length are excellent fasteners that are commonly available (Zeleny 1976). Henderson (1984) recommended concrete coated or ring shank nails for cedar and redwood boxes to prevent boards from loosening during the weathering process. Although slightly more expensive, nails with roughened shanks are superior to smooth nails because they hold the boards together more tightly (Zeleny 1976). A wood screw and washer, rather than a nail, should be used on the box side that opens; brass screws are preferred because they will not rust (Kibler 1969) and are easy to remove. If a hinge is used on the top-opening box instead of the dowel and cleats, it should be a 2-in.-wide brass hinge attached with 3/4-in. wood screws; the top may then be secured in the closed position with a single screw (Zeleny 1976). Boxes should be assembled carefully to prevent hazards that could injure birds; nails should not protrude into the interior of the box, and gaps should not be left to catch a young bird's claw (Obee 1984).

Paint. It is not necessary to paint nest boxes made of durable wood (Gary and Morris 1980), but paint may add years to the life of a softwood box (Zeleny 1976). Unpainted boxes are relatively inconspicuous and have more aesthetic appeal if allowed to weather naturally and blend with surrounding vegetation. If boxes are painted, a water-based, exterior latex should be applied, and painting should be completed at least 2 weeks before box placement (McNeil 1979). A light color is recommended to prevent overheating of eggs or young; temperatures in dark-colored bluebird boxes have been found to be as much as 12° F higher than in light-colored boxes of the same design and construction (Zeleny 1968). Shades of green, gray, and tan are the most satisfactory colors for nest boxes and should be applied only to the exterior surfaces (Zeleny 1976). Paints containing lead or chemical preservatives such as those listed above should not be used because of their potentially harmful effects to wildlife.

Design Alternatives

Bluebird boxes. Several modifications of the generalized nest box design are presented in this report. McComb et al. (1987) investigated bluebird use of boxes with a slot entrance. The front of the box contained no hole but was cut short enough to leave an opening 1-1/2 × 5 in. at the top of the panel. In this Kentucky study, bluebirds preferred boxes with the slot entrance rather than the standard circular entrance. Further research indicated that a slot of 1.2-in. width was necessary to eliminate starling competition.

The Bauldry box has several special features (Missouri Conservation Commission 1980) (Fig. 4). The flat roof contains a 3-1/2-in. hole covered

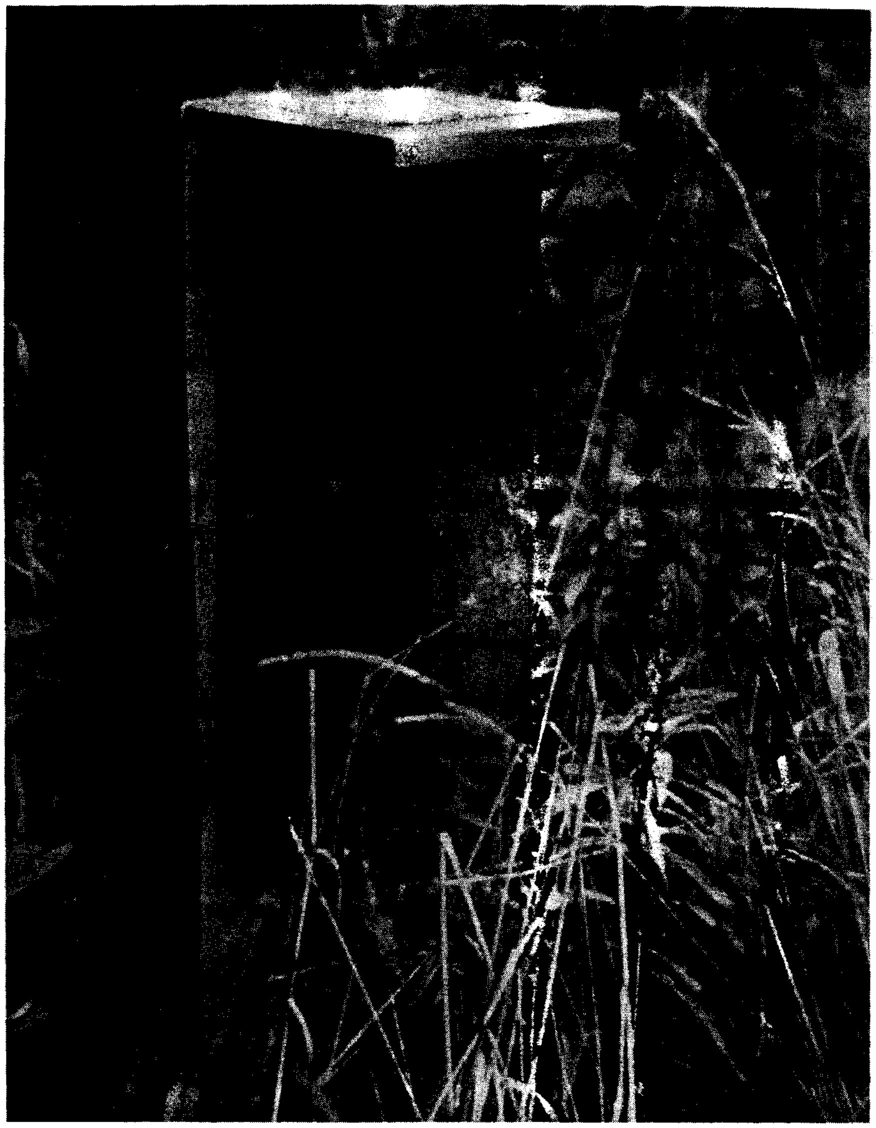


Figure 4. The Bauldry box features a thickened entranceway useful in controlling predators

with hardware cloth; the opening allows water to enter, which will not harm the nestlings if protected by parents but discourages sparrows from nesting. Another feature of this box is the 1-1/2-in. wooden block placed in front of the entrance so that its opening coincides with the entrance hole. The thickened entranceway prevents raccoons (*Procyon lotor*), domestic cats (*Felis catus*), and other predators from reaching the nest contents, and starlings have difficulty entering the box.

Peterson (1987) devised an alternative nest box structure for bluebirds by excavating cavities in the tops of fence posts and covering each cavity with a roof. This structure was developed primarily to reduce box visibility along interstates and thus to eliminate safety problems caused by passing motorists trying to observe the birds. Tree swallows used the boxes more than did bluebirds, but both species nested successfully in the fence post cavities. Caution is suggested in using this nest structure, as fence posts are often treated with preservatives.

Special boxes. Although dimensions of the bluebird nest box can be easily modified to accommodate most cavity nesters, specialized house designs have been developed for some species. A small, free-swinging box can be constructed for wrens (Fig. 5), and a bark-covered house that attaches to tree trunks can be built for nuthatches, chickadees, and titmice (Fig. 6). The nest shelf is an open modification of the nest box and can be used to attract robins, house finches, phoebes, and barn swallows (Sawyer 1955, Kalmbach and McAtee 1969, Henderson 1984) (Fig. 7). Sawyer (1955) recommended that 3 sides of the shelf be closed for house finches. A narrow strip placed across the front of the shelf floor may help protect the initial nest material from high winds, and a few small drainage holes drilled in the floor will prevent moisture from accumulating in the nest.

Communal houses (apartments) are required for purple martins, which are colonial cavity nesters (Sawyer 1955) (Fig. 8). Specifications for these houses are presented in Figure 9. Because the design is intricate and construction is time-consuming, purchase of preconstructed houses may be a more feasible alternative for the wildlife manager.

Gourds are readily accepted by martins, wrens, tree swallows, and great crested flycatchers (Davison 1967). A round opening should be cut in one side of the gourds, which may then be erected fairly easily on poles or wire strung like a clothesline.

Plastic boxes. Nest boxes constructed of rigid PVC (polyvinyl chloride) pipe are now being used in some nest box programs. Although wooden boxes are more natural and aesthetically pleasing, PVC structures are generally less expensive to construct and maintain and have a potentially longer functional life (estimated at 20 to 25 years). The only labor required for songbird nest boxes (made from 4- to 6-in.-diam PVC) is for cutting the pipe to length, cutting an entrance hole, attaching endcaps, drilling ventilation and drainage

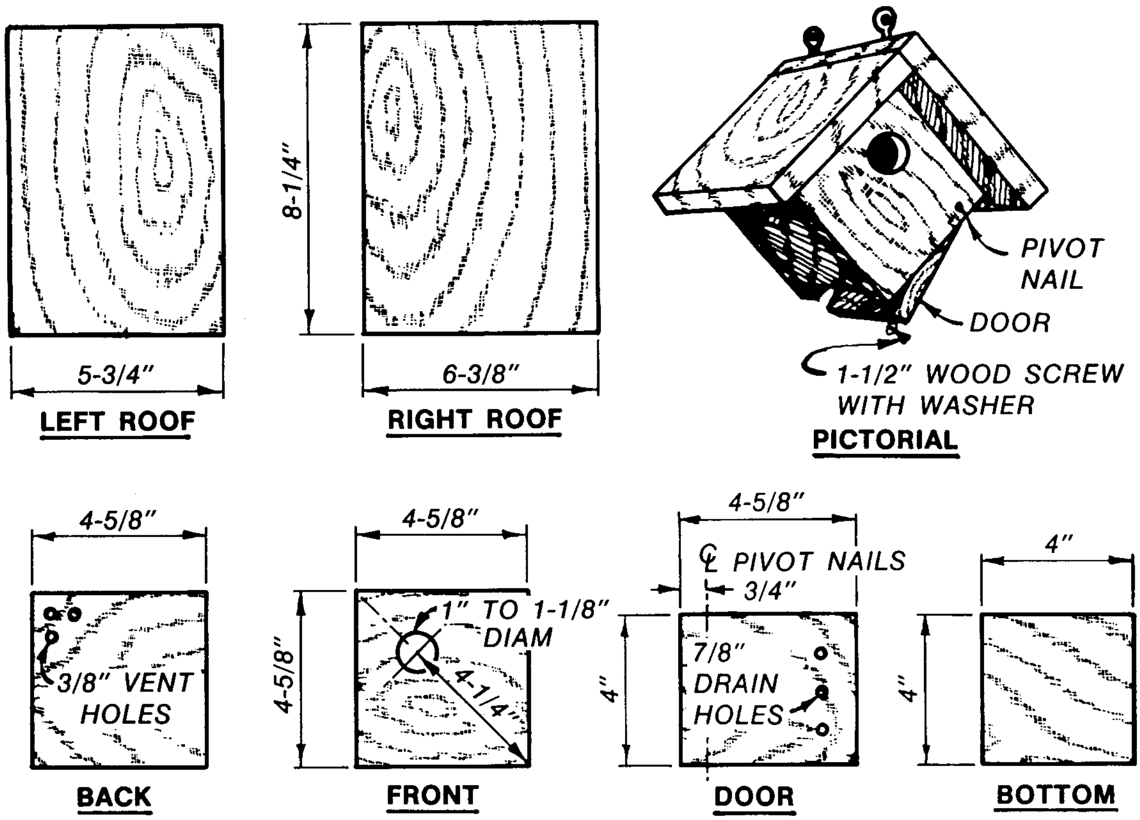


Figure 5. Construction details for a wren house (after McNeil 1979)

holes, and painting the boxes in light, earth tones. Boxes can be attached to wooden supports using lag screws drilled through the back; plastic or metal bands can be used to attach boxes to a metal support (John P. Pasa, US Army Corps of Engineers, Rathbun Lake, Iowa, pers. commun., 1988).

PVC boxes were well used by target species (eastern bluebird, purple martin, American kestrel, wood duck) during the first year after placement at Rathbun Lake, but these structures must be considered experimental until additional data have been collected on use and nesting success. A recent study showed that overheating of plastic wood duck boxes exposed to sunlight reduced duck production (Hartley and Hill 1988). Therefore, biologists should use caution when installing PVC structures for songbirds, and the boxes should be carefully monitored to assess potential adverse effects of high temperatures.

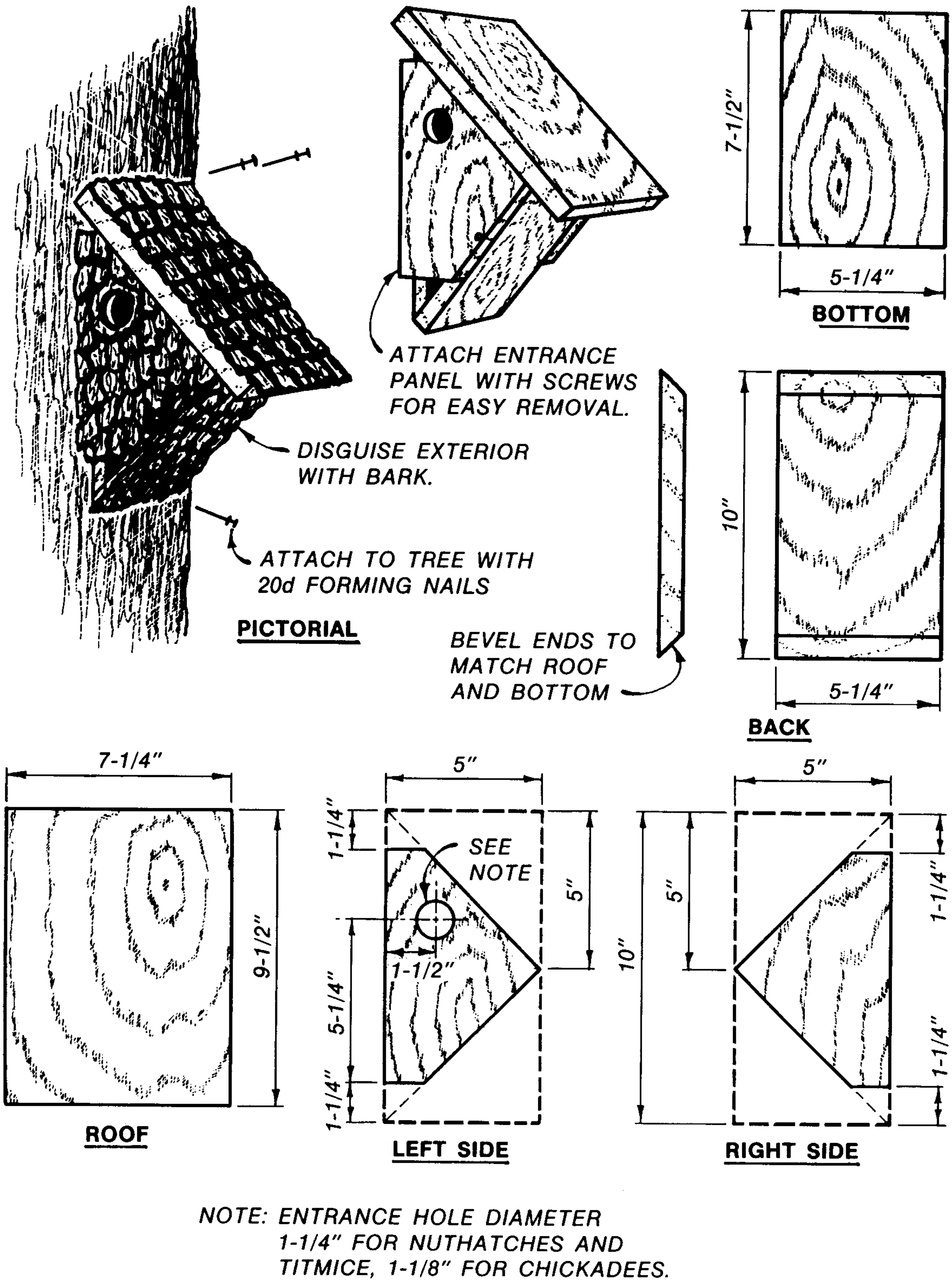


Figure 6. Construction details for a nest box that can be used by nuthatches, chickadees, and titmice (after McNeil 1979)

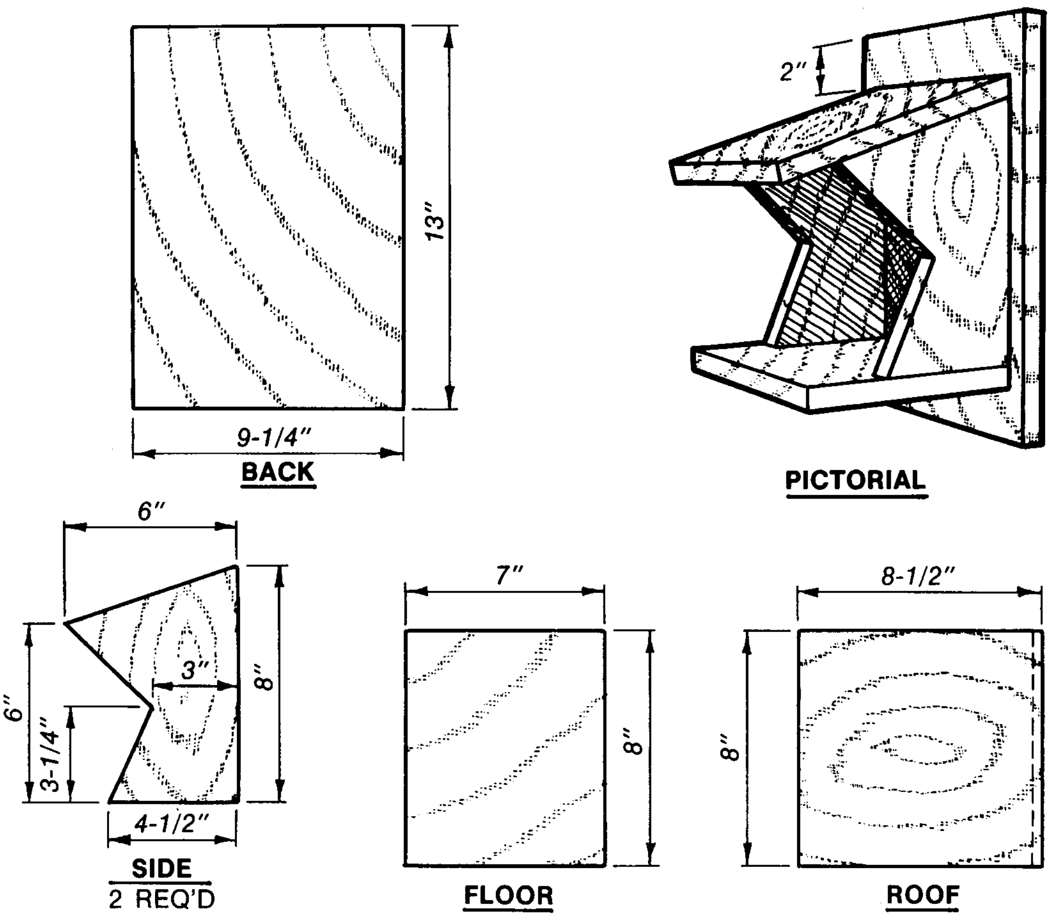


Figure 7. Construction details for a nesting shelf (after Henderson 1984)

INSTALLATION

Timing

New nest boxes should be installed in advance of the nesting season, preferably in late winter for most songbirds (Mississippi State University 1981). It is important to know the arrival time of desired species, as early preparation of boxes offers nest options for migrants that scout the area before the beginning of nesting season (Rustad 1972a). Laskey (1940) found that boxes placed for bluebirds in late March and early April in Tennessee were too late for use by permanent residents, which investigated possible nest sites on mild days in winter and early spring. Zeleny (1973) recommended that bluebird boxes be placed by mid-February in the South and by mid-March in the North.

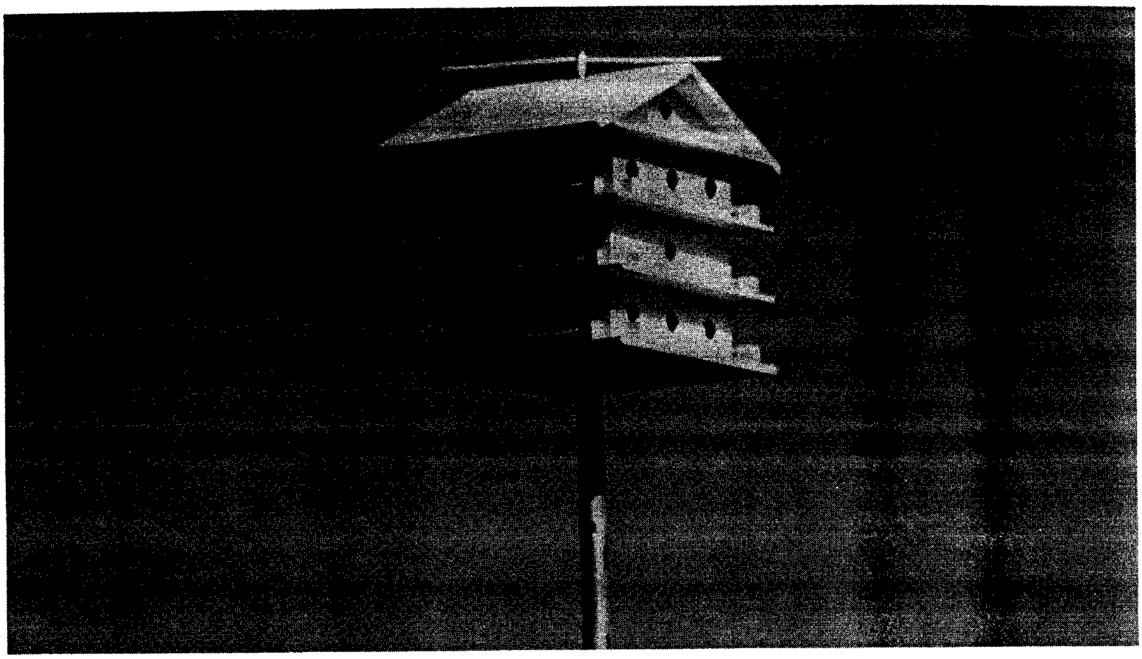


Figure 8. Communal house constructed for purple martins

However, Hamilton (1943) found that bluebirds may arrive in late February in northern states; therefore, early placement of boxes is preferable.

It is critical to have boxes prepared early for species that nest only once a year, such as the tree swallow. Henderson (1984) recommended box placement before May 1 for tree swallows in the northern states. After initial placement, additional boxes may be erected later in the season for species that produce more than one brood per season.

Mounting

Supports. Nest boxes should be firmly attached to durable supports. New wooden or metal posts are preferable, but boxes may be installed on existing supports such as fence posts, trees, buildings, and utility poles. Boxes mounted on pasture fence posts should be placed on the side away from livestock to prevent animal damage, and those mounted on trees should be placed on the open trunk rather than among branches (Mississippi State University 1981). Wren houses, however, may be suspended from an anchor point under a tree limb or building eave (Henderson 1984). Utility poles make excellent supports, but permission must be obtained for mounting the boxes (Zeleny 1976).

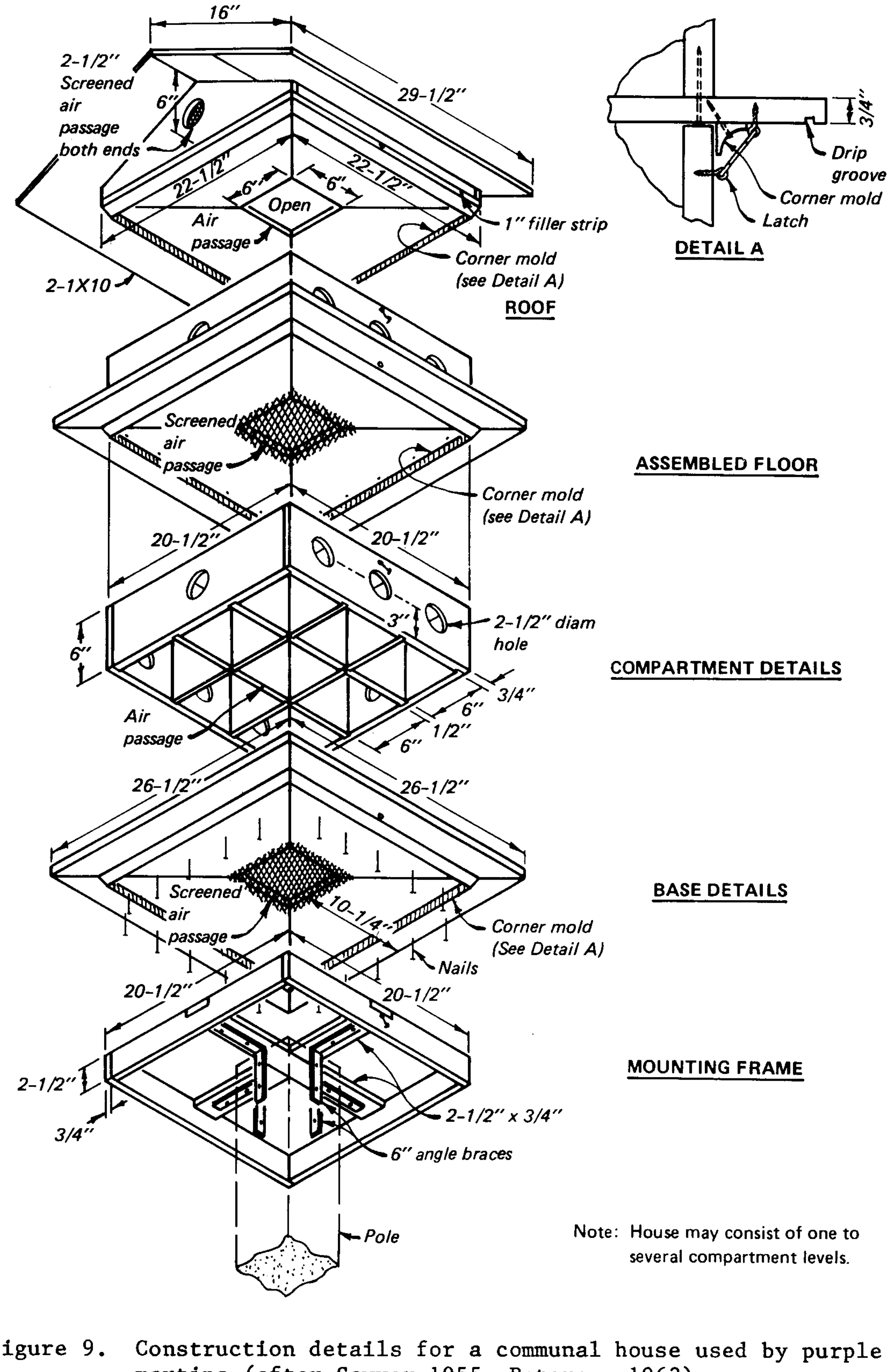


Figure 9. Construction details for a communal house used by purple martins (after Sawyer 1955, Peterson 1963)

Songbirds have readily accepted boxes mounted on other types of supports. For example, boxes attached to rural mailbox posts directly beneath the mailboxes were used by bluebirds in Ohio (Zeleny 1976), and 16 boxes placed inside the 2-1/2-ft-high support posts of the metal guard rail along the top of Arkabutla Dam, Mississippi, resulted in 95% to 98% nesting success (Clossin and Hearn 1983). Although a variety of supports may be used, sturdiness and durability are the main criteria for any support.

Boxes may be attached to tops or sides of wooden posts by means of screws or nails through holes in the back boards or may be bolted or wired to tops or sides of metal posts (Mississippi State University 1981). When metal posts are used, U-shaped pieces of No. 14 galvanized wire may be slipped through the small holes in the back boards and twisted tightly around the posts for secure mounting (Zeleny 1976) (Fig. 3). Boxes may be mounted on smooth metal posts such as 1/2-in. or 3/8-in. inside diameter galvanized water pipe by means of a pipe flange, which is available at hardware stores, and a pipe auger can be used to install the pipe to a depth of 2 ft in the ground (Zeleny 1973). Lag screws and washers should be used to secure a box to a live tree so the screws can be gradually loosened to accommodate tree growth (Henderson 1984).

Height. Cavity-nesting birds tend to select tall snags for natural nest sites (Taylor 1965, Mannan et al. 1980, Raphael and White 1984). However, most cavity nesters readily accept artificial nest sites placed at much lower elevations than natural cavities. The height at which a box is mounted is not critical if predation is absent or controlled. Boxes for most songbirds can be mounted within reachable distances from the ground for easy monitoring and maintenance. Suitable nest box heights for a variety of species are provided in Table 2, and the minimum heights suggested for most species are readily accessible from the ground, especially for the smaller cavity nesters.

Identification. To facilitate record keeping, boxes should be numbered in an ordered sequence within a given area or along a trail (Zeleny 1976). It is recommended that a readily visible numeral be painted on each box and that, for aesthetic reasons, it be neat and of reasonable size (Fig. 10). If individuals or organizations have contributed to the nest box project, a small name plate or label designating those responsible may be attached to each box to help discourage vandalism. Later in the season, plastic tape may be placed on posts to identify boxes with active nests (Hurst 1983).

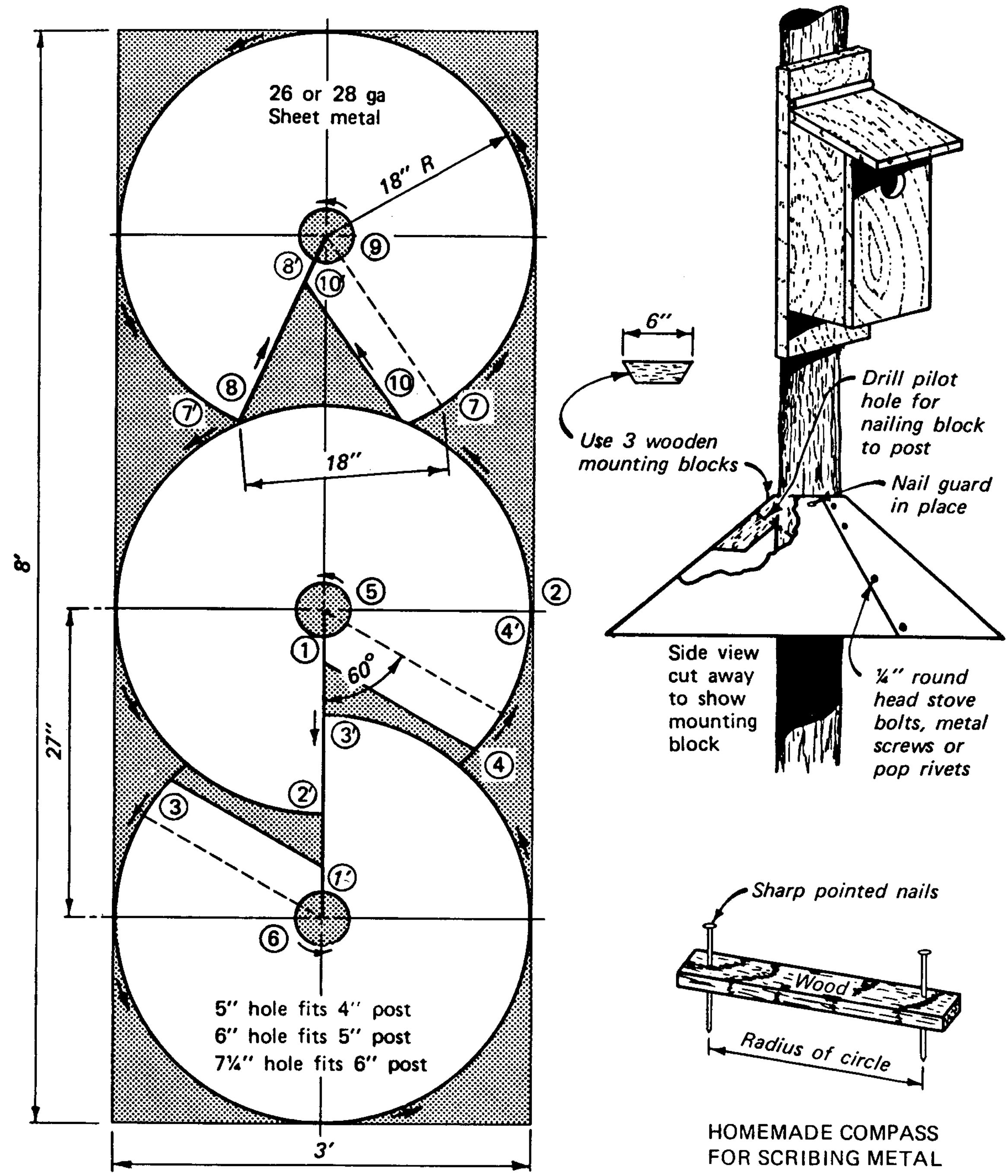
Figure 10. A neat, readily visible number should be painted on each box along a trail

Predator Guards

Nest boxes may require the addition of predator guards to provide extra protection. The most widely used guard is the cone-shaped metal shield illustrated in Figure 11. It is designed primarily for boxes mounted on posts and can be nailed or stapled under the box to deter predators attempting to reach the nest. Webster and Uhler (1964) recommended using 26-gauge, 30-in.-wide galvanized tin or aluminum to construct this guard. The predator guard shown in Figure 4 can be made from a wooden block that is 1-1/2 in. thick; it should be attached firmly to the front of the box so that the hole coincides exactly with the entrance hole (Mississippi State University 1981). Metal predator guards should be painted with a flat paint to eliminate glare.

Nest Material

Nest substrate should not be provided in small boxes because secondary cavity nesters prefer to select their own material (Gary and Morris 1980). Birds searching for a nest site may reject a box containing material because



To facilitate cutting (on solid lines only) follow the sequence of numbers. Complete each cut before initiating the next (e.g. 1 → 1' then 2 → 2'). Make circular cuts in counterclockwise direction. To make initial cut at 1 make slot with cold chisel. Cut complete circles at 5, 6, and 9. When installing guard, overlap the cut edge to the dashed line. Three guards can be cut from an 8'X3' piece of sheet metal.

Figure 11. Construction details for a conical sheet metal predator guard (modified from USFWS 1976)

it would appear to belong to another nesting pair (Peterson 1963). Large boxes are used mostly by primary cavity nesters that do not build nests and, therefore, need to have a 1- to 2-in. layer of material covering the bottom so that a cavity can be shaped for the eggs (Gary and Morris 1980). Suitable substrates include wood shavings, ground cork, small chips, and coarse sawdust; fine chips may be used for smaller species such as downy and hairy woodpeckers (Kalmbach and McAtee 1969). Henderson (1984) recommended filling flicker boxes to the top with coarse sawdust and tamping firmly; the filled box simulates a dead tree with soft heartwood, and the flicker will excavate sawdust until a nest cavity is formed. A hinged roof facilitates filling the box completely.

PLACEMENT

Location of nest boxes in suitable habitat is essential to the success of a nest box program. Selection of good locations is actually more critical than box design; therefore, habitats selected for box placement should be consistent with habitat preferences of target species (Zeleny 1976) (Table 3).

Suitable Habitats

Open habitats. Species that nest in open habitats include the bluebirds, tree and violet-green swallows, purple martin, northern flicker, and ash-throated and great crested flycatchers. Good locations for nest boxes are pastures, fields, country cemeteries, golf course roughs, open lands, large lawns (Zeleny 1976), orchards, shelterbelts, prairies, road or powerline rights-of-way (Henderson 1984), and clearcut areas (Conner and Adkisson 1975).

Although use will be relatively brief, boxes may be placed in openings of regenerating forests. Hurst (1983) found that eastern bluebirds and Carolina chickadees used boxes during the first 7 years of loblolly pine (*Pinus taeda*) regeneration in the Southeast, and Zarnowitz and Manuwal (1985) observed that tree swallows and western bluebirds nested in the early successional stages of western hemlock (*Tsuga heterophylla*) - Douglas-fir (*Pseudotsuga menziesii*) forests of the Pacific Northwest.

Ideal habitat for the eastern bluebird is away from urban areas and farm buildings with their many house sparrows and starlings (Zeleny 1976). Bluebirds prefer open areas with grass or low vegetation and scattered trees, especially if low dead branches are present for foraging perches; areas of low

Table 3. Habitats preferred by cavity-nesting songbirds (after Peterson 1980, National Geographic Society 1983)

Species	Preferred Habitat
American robin	Urban and suburban areas, backyards, farmlands, parks, moist woodlands, swamps
Eastern bluebird	Open woodlands, farmlands, pastures, fields, orchards
Mountain bluebird	Open rangelands and meadows above 5000-ft elevation
Western bluebird	Open woodlands, farmlands, orchards
Chickadees	Open woodlands, clearings, edges, suburban areas
Titmice	Woodland, woods edges
Ash-throated flycatcher	Desert, chaparral, dry open woods, woods edges
Great crested flycatcher	Open deciduous forests, woods edges, pastures, orchards
Black phoebe	Woodlands, parks, suburbs, near water
Eastern phoebe	Woodlands, farmlands, suburbs, streamsides, roadsides, nests under bridges and barn eaves
Say's phoebe	Dry open areas, canyons, cliffs
Nuthatches	Woodland clearings and edges
Prothonotary warbler	Moist forest bottomlands, wooded swamps, flooded river valleys
Barn swallow	Open or semi-open country, marshes, lakes, farm buildings, nests under bridges and barn eaves
Purple martin	Open or semi-open country, farmlands, towns, often near water
Tree swallow	Wooded areas near water, pastures, fields
Violet-green swallow	Open woodlands, suburbs, coastal areas
Downy woodpecker	Woodland clearings and edges, parklands, orchards, backyards
Golden-fronted woodpecker	Dry woodlands, woods edges, pecan groves, mesquite brushlands
Hairy woodpecker	Dense mature forests, river groves, backyards
Lewis' woodpecker	Open woodlands, coastal areas
Northern flicker	Open forests, woodlots, farmlands, groves, semi-open country, suburban areas

(Continued)

Table 3 (Concluded)

Species	Preferred Habitat
Pileated woodpecker	Dense, mature conifer, mixed, and hardwood forests; woodlots, parklands
Red-bellied woodpecker	Open woodlands, groves, orchards, backyards
Red-headed woodpecker	Open woodlands, woods edges, farmlands, bottomlands, orchards, backyards
Yellow-bellied sapsucker	Deciduous forests, aspen groves
Bewick's wren	Brushland, open woodlands, stream edges, hedgerows, backyards
Carolina wren	Underbrush of moist woodlands and swamps, wooded suburban areas, woods edges
House wren	Brush and shrubs of woodland clearings and edges, orchards, backyards, parks

soil fertility are often favored by bluebirds because these areas support only sparse vegetation conducive to foraging (Zeleny 1976, Willner et al. 1983). If boxes are located near woodlands, the entrance should face the open habitat (Pitts 1976).

Thickets or shrubs should be present in the vicinity of boxes intended for species that nest in brush. Thickets may be encouraged by allowing weeds, tall grass, brambles, and shrubs to grow uninhibited and form a dense tangle of not less than 400 sq ft (Sawyer 1955).

Woodlands. Cavity nesters that prefer woodland clearings and edges include western bluebirds (Gary and Morris 1980), wrens, chickadees, nuthatches, titmice (Zeleny 1976), and the hairy, downy, and red-headed woodpeckers (Conner and Adkisson 1977). Boxes for the northern flicker and flycatchers may also be placed in woodland openings, and the great crested flycatcher will use boxes attached to pine trees in mixed conifer and hardwood stands (Henderson 1984). Boxes for the pileated woodpecker should be located in extensive forest stands (Conner et al. 1975). In Oregon, pileated woodpecker cavity nests were found in the most dense forest types (Bull and Meslow 1977), and those in a Virginia study were typically found within 250 ft of small streams in stands of high basal area and tall canopy (Conner and Adkisson 1977); however, the pileated woodpecker has been reported to occasionally nest in clearcuts and forest edges (Bent 1939, Conner et al. 1975).

Aquatic sites. Ideal habitat for some cavity nesters includes water; this should be taken into consideration when locating nest boxes for the prothonotary warbler, eastern phoebe, barn swallow, and tree swallow. Prothonotary warblers prefer to nest above water in lowland hardwood forests but will occasionally use upland sites near water. Boxes may be placed on posts in shallow woodland pools, marshes, or oxbow ponds of river bottoms (Henderson 1984); if placed on land, boxes should face the water.

The tree swallow prefers sites near bodies of water such as lakes, rivers, and marshes (Rustad 1972b, Yoakum et al. 1980). It readily accepts bluebird boxes for nesting but is less selective of habitat type than the bluebird (Munro and Rounds 1985); therefore, competition between these two species may be reduced or avoided by placing boxes intended for tree swallows near water and those for bluebirds in open areas well away from water (Rustad 1972b).

Urban settings. Most species that nest in open habitats or woodland edges can be attracted to urban sites if sufficient foraging habitat is available. Nesting shelves may be placed in backyards for the American robin, barn swallow, cliff swallow, and phoebes. Wren houses may be hung from tree limbs or the eaves of buildings, and boxes for nuthatches, chickadees, and titmice may be located around yard or woodlot edges. The purple martin is readily attracted to large open lawns; the northern flicker will nest in orchards, woodlots, and yards (Henderson 1984); and barn swallows particularly like to build nests around barns and other old buildings.

Songbird trails. An effective method of nest box placement is to arrange boxes along a trail with spacing at appropriate intervals to prevent territorial conflicts. The trail has been highly successful in efforts to restore eastern bluebird populations and may be designed chiefly for one species. However, it is especially well adapted for use in park settings and around campgrounds, as boxes can be located in diverse habitats to attract a variety of species. Either of two approaches may be used in developing such a trail for multiple species use: (1) boxes may be constructed for species expected to nest in the habitats through which the trail will pass or (2) the trail may be laid out through the nesting habitats of desired species. In the latter case, boxes should be constructed specifically for potential species, and spacing requirements should be carefully observed. Trails laid out in loops facilitate monitoring and encourage public use in recreational areas.

Foraging Considerations

The success of a nest box program will depend to a large extent on the presence of adequate foraging habitat in the vicinity of sites selected for box placement. Therefore, it is important to know the foraging habits of desired species so that boxes can be located near preferred feeding habitat if not directly in it. For example, the red-headed woodpecker may nest in dense forest but requires an open understory or a nearby clearing to catch insects in the air and on the ground (Reller 1972, Conner and Adkisson 1977).

Boxes for species that nest in open habitats are usually placed within or along the edges of such habitat. However, these birds forage in the open and need perches from which to spot prey (Henderson 1984). Sites selected for box placement should contain natural perches, such as snags and scattered vegetation, or artificial structures such as fences, power lines, telephone poles, posts, and street signs (Zeleny 1976, Pinkowski 1979, Willner et al. 1983).

Because nest boxes substitute for natural cavities, it might be assumed that they should be located in areas devoid of snags (dead or dying trees). However, a site with a few snags should be given priority when placing boxes for primary cavity nesters. Snags are important foraging substrate for these species because they harbor insects and insect larvae, especially beetles (Conner 1978, Mannan et al. 1980). Although snags at an otherwise appropriate location might not be adequate for nest sites, they may serve as foraging habitat for a nesting pair.

Snags are the major feeding habitat for most primary cavity nesters, but some will forage on other substrates. The yellow-bellied sapsucker, black-capped chickadee, and tufted titmouse foraged in live trees in the oak-hickory forests of Missouri (Brawn et al. 1982), and the northern flicker, pileated woodpecker, and hairy woodpecker searched for insects on the ground, live trees, downed logs, and stumps in Douglas-fir forests of western Oregon (Mannan et al. 1980). Snags are particularly important for resident species during winter when insects are scarce and other substrates are covered with snow (Conner et al. 1975, Bull and Meslow 1977). If providing or maintaining suitable habitat for cavity nesters is a management objective, consideration must be given to resources required by resident species during all times of the year (Brawn et al. 1982).

Spacing

Gary and Morris (1980) recommended 2 to 4 small nest boxes per acre or 1 nest box per 10 acres for large cavity nesters. Nest boxes for a given species must be spaced far enough apart to avoid conspecific competition. For example, bluebird boxes should be at least 100 yd apart (Zeleny 1976, Yoakum et al. 1980, Hurst 1983), but boxes for tree swallows may be spaced from 75 to 100 ft around ponds or in marshes (Ebert and Francis 1978). Although the minimum distance between boxes will depend primarily upon the territorial requirements of a species, quality of habitat is also a consideration for spacing boxes appropriately. Although desirable, it is not always possible to place boxes in the highest quality habitat preferred by a target species. Those located in marginal habitat need to be spaced at greater distances to accommodate larger foraging territories.

Orientation

There are conflicting opinions about the orientation of natural nest cavities. Nonrandom orientation was reported for woodpecker cavities in central Ontario (Lawrence 1967), Iowa (Stauffer and Best 1982), and Colorado (Inouye 1976, Scott et al. 1980). However, other studies have indicated that environmental factors may influence nest orientation. Significantly more cavities were oriented away from prevailing winds in Michigan (Pinkowski 1976) and Virginia (Conner 1975) and toward prevailing winds in Arizona (Austin 1974) and Illinois (Reller 1972). Austin (1974) suggested that cactus wrens orient their nests toward prevailing winds to provide suitable nest climate during the hot months of the breeding season. Natural nest cavities observed by Lawrence (1967), Dennis (1969), and Reller (1972) were oriented in a southeasterly direction; therefore, these workers have suggested that the sun's warmth was the major factor influencing nest orientation.

It is generally recommended that a nest box be positioned so the entrance faces away from prevailing winds, thus reducing the potential hazard of cold driving rain. Protection from spring rains is not usually critical for bluebirds if the roof overhang is sufficient and the box is deep enough (Rustad 1972a). However, orientation away from the wind may be more critical for tree swallows; in a nest box project in Minnesota, 92 young birds were lost during adverse weather in the spring of 1968 (Rustad 1972b).

Zeleny (1976) stated that the orientation of a bluebird box has little influence on its interior temperature, except on windy days. However, boxes erected for birds nesting in open habitats of very hot regions may be placed in the shade of large isolated trees or attached to the north or northeast side of utility poles. Boxes in open habitats should face at least 1 perch structure such as a tree, shrub, or fence high enough to provide protection for fledglings leaving the nest (Gary and Morris 1980).

MAINTENANCE

Maintenance consists of the inspection, cleaning, and repair of used nest boxes; it includes removing existing nest material and debris, opening clogged drains, and repairing boxes and supports (Zeleny 1976, Mississippi State University 1981). Maintenance should be completed by late winter in preparation for the early arrival of nesting pairs. Boxes may be cleaned and repaired in the fall; however, inspection will be required again before nesting season because some boxes may have served as winter roost sites for resident birds or small mammals.

During the nesting season, frequent inspection may be required to prevent undesirable species such as starlings and house sparrows from usurping nest boxes (Zeleny 1976). As these species are not protected by state or Federal law, their eggs and nests should be removed immediately (Henderson 1984). Both species construct bulky untidy nests that may fill an entire box. Those of starlings are composed primarily of stems and leaves, but house sparrow nests may contain feathers, assorted litter, and even garbage (Henderson 1984). Starling eggs are pale blue and glossy (similar to bluebird eggs), whereas sparrow eggs are white with brown markings. Nests may have to be removed 5 or 6 times before the birds will abandon a box. If they are particularly persistent, the entrance hole may be covered for a few days to encourage them to look elsewhere for a nest site (Zeleny 1976).

Boxes should be examined for insect infestations during routine inspections. Fleas, lice, and flies are usually only a nuisance, and boxes will need no treatment unless they are abundant (Kalmbach and McAtee 1969). If ants are a problem, a commercial preparation may be poured into a bottle cap and placed under the nest (Henderson 1984). Blowfly eggs and larvae may be detected by lifting and gently tapping the nest; larvae will fall through and can be removed from the box floor. Zeleny (1976) recommended replacing the nest material with dry grass if bluebird nestlings appeared weakened or poorly developed in a nest heavily infested with blowfly larvae. The interior of the box may also be sprayed with a disinfectant to prevent formation of wasp nests in areas where these insects are a problem (Henderson 1984).

Boxes should be opened cautiously because wasps frequently attach their nests to the underside of the roof. Active wasp colonies inhibit nesting and should be removed (Zeleny 1976). Henderson (1984) recommended carrying a can of aerosol insecticide for self-protection.

Top-opening boxes produce the least interference with nesting birds; opening a box from the side may stimulate nestlings to leave the box prematurely (Zeleny 1976). Unless there are definite signs of trouble, a quick inspection will suffice while nestlings are in the box.

Boxes should be cleaned as soon as broods have left, even if adult birds show signs of using the box again (Kalmbach and McAtee 1969). Prompt removal of old nest material increases the chances of second or third broods (Mississippi State University 1981). This is especially important for species such as the tree swallow that nest only once each year, for it frees boxes that may be used by multiple-brood species such the bluebirds (Henderson 1984). Eggshells, dead nestlings, and old nests should be discarded and burned (Kalmbach and McAtee 1969), and the interior of the box should be treated with 1% rotenone powder or a pyrethrin spray if the nest material contains mites or larvae (Zeleny 1976). If a new nest is being built over the old one, the box is best left undisturbed.

Winter use of boxes may be prevented by leaving front or side panels open (Henderson 1984), corking entrance holes (Kibler 1969), or removing and storing boxes (Rustad 1972a). Removal of boxes will help slow deterioration but is time consuming and may not be cost effective. Furthermore, management for species diversity would be enhanced by providing boxes for alternate wildlife use.

EVALUATION

The success of a nest box program depends upon the achievement of management objectives. Boxes erected in park settings or in suitable habitats with few nesting sites may be considered successful if songbirds use the boxes. However, productivity of target species is important in the evaluation of a project designed to increase or restore populations limited by the availability of nest sites.

Nest Box Use

Data collected during a fall inspection are sufficient to determine nest box use; these should reflect whether a box was used that year and by which species. Nest box use can be reported as a percentage of total boxes available at a site or within a management unit. Box use will likely vary by habitat type and quality. For example, only 30% of the boxes at one site may be used, whereas 60% may be used at a site with better foraging habitat. Although occupancy rates of more than 80% have been reported (Musselman 1935, Willner et al. 1983), it would be unrealistic to expect 100% use on most projects. Management objectives will have been met if box use is consistent with habitat capability to support cavity nesters at a site.

Nest box use may be poor the first year because of low discovery rates (Gano and Mosher 1983) but will usually increase in subsequent years. For example, 50 nest boxes designed for the eastern screech-owl received low use during the first winter and spring in woodland sites of eastern Tennessee; however, by the third spring, 45% of the boxes were used by screech-owls and other species (Fowler and Dimmick 1983). During 3 breeding seasons, box use increased from 5% to 31% in ponderosa pine (*Pinus ponderosa*) forests of northern Arizona; not only did more birds nest in boxes each year, but more species used the boxes by the third year (Brawn and Balda 1983).

Nest Success

Data collection. Evaluation of nest success requires that boxes be monitored during the nesting season. The intensity of monitoring will depend upon program objectives. During a visit to the nest, care should be taken to minimize disturbance. The American Ornithologists' Union (1988) pointed out that nest visitation may impact birds and recommended the minimal number of visits required to collect the needed data.

Boxes should be monitored several times during the summer to obtain at least the following data for each nesting species: (1) number of boxes containing nests, (2) number of boxes with eggs, and (3) number of boxes fledging young. If more detailed results are needed, the following data can be collected for each nesting attempt: (1) number of eggs per clutch, (2) number of eggs hatched, (3) approximate hatching date, (4) number of surviving nestlings at each inspection, (5) number of nestlings fledged, (6) approximate date of fledging, and (7) probable causes of egg or nestling loss.

Results. Results of nest box studies have been quantified in several ways. VanCamp and Henny (1975) and Hurst (1981) considered a nest successful if it produced at least 1 fledgling. Other biologists have measured nest success by the percentage of eggs that produced fledglings (Laskey 1943, Miller 1970, Rustad 1972a) or the percentage of boxes from which young were fledged (Petersen 1969). The following examples illustrate the apparent disparity in nesting success when results are quantified differently.

Based on the percentage of nests fledging young, nest success has been reported as 68% for western bluebirds in Colorado (Gary and Morris 1980), 81% for eastern bluebirds in Mississippi pine plantations (Hurst 1981), and 86% in a 30-year study of eastern screech-owls in Ohio (VanCamp and Henny 1975). Success rates appear to be lower when based on the percentage of boxes fledging young because some boxes will not be used; Petersen (1969) found that only 17% to 44% of boxes produced fledglings in an 8-year study of eastern bluebirds in Iowa. When success was measured by the percentage of eggs producing fledglings, Laskey (1943) found 45% nest success for eastern bluebirds, and Miller (1970) found a success rate of 45% for mountain bluebirds and 54% for eastern bluebirds.

The definition of nesting success should relate to the goals of the nest box program. Success based on the percentage of boxes producing fledglings requires the least extensive data collection and should provide sufficient information to evaluate a program established to increase the availability of nest sites. However, more detailed results would be required to measure productivity of a songbird population in a given area, and information would be needed on the percentage of eggs that hatched and produced fledglings or the mean number of young fledged per successful nest. Regardless of its extent, a nest box program should include a means to evaluate the accomplishment of program objectives.

PERSONNEL AND COSTS

Estimates of initial project costs are based on the cost of materials and time required for construction and installation of nest boxes. Thereafter, major costs will be for manpower to inspect and maintain boxes and will depend chiefly upon the number of inspections conducted during the nesting season.

Materials

Lumber represents the largest expenditure for materials; the amounts needed to construct each box illustrated in this report are given in Table 4. Because most boxes require more than one width of lumber, it is cost effective to use several sizes of boards when building a large number of boxes. For example, 1 top-opening bluebird box requires 4 board-feet (bd-ft) of 1 × 8 × 6-ft lumber; this is a total of 40 bd-ft per 10 boxes if 1 box is cut from a single board. However, material for 10 boxes can be reduced by approximately 1 bd-ft per box by cutting the roofs from a 1 × 8 × 6-ft board and the rest of the pieces from five 1 × 6 × 10-ft boards. Only a few boxes of special design may be needed in a nestbox program. Several of the small boxes can be cut from 1 board, whereas the martin house shown in Figure 9 requires at least 55 bd-ft of lumber of various sizes.

Personnel

Construction. Construction time for bluebird nest boxes should average 1 man-hour per box, or 12.5 man-days per 100 boxes. The nuthatch box can be built in approximately the same amount of time, but the wren house and nest shelf will take less time because there are fewer pieces to cut and assemble. Because of its complex design, the martin house requires 8 to 10 hours for a skilled carpenter to build; therefore, it is recommended for construction only by personnel with carpentry expertise and specialized tools. The purchase of preconstructed martin boxes may be the most economical alternative for a purple martin nest box program.

Installation. Installation time for boxes mounted on new supports should average from 0.5 to 0.75 man-hour per box, or 6 to 10 man-days per 100 boxes, but placing boxes on existing supports such as fence posts or tree trunks will reduce manpower requirements by 50% to 75%. The time needed to build predator guards is approximately 0.25 to 0.5 man-hour per box, or 3 to 6 man-days per 100 boxes. Manpower estimates include the time required for all aspects of construction and installation, including assembly of materials, site selection, placement of nest boxes, and cleanup.

Maintenance. Maintenance of boxes once a year should average approximately 0.3 to 0.5 man-hour per box, or 4 to 5 man-days per 100 boxes. Boxes that are monitored to collect data may require less time per visit because tasks such as spraying and removal of nest contents will not be necessary at each visit, but more inspections will be needed during the nesting season.

Table 4. Lumber needed to construct the nest boxes described in this report

Type of Box	Quantity	Lumber Requirements Bd-ft	No. Boards	Board Dimensions
Bluebird box (top-opening)	1	4	1	1 × 8 × 6 ft
	10	29		
		4	1	1 × 8 × 6 ft (roofs)
		25	5	1 × 6 × 10 ft
Bluebird box (side-opening)	1	5	1	1 × 10 × 6 ft
	10	39		
		7	1	1 × 10 × 8 ft (roofs)
		32	4	1 × 8 × 12 ft
Wren house	2	4	1	1 × 8 × 6 ft
	4	8	1	1 × 8 × 12 ft
Nuthatch box	2	6	1	1 × 8 × 8 ft
Nest shelf	2	7	1	1 × 10 × 8 ft
	5	16		
		5	1	1 × 10 × 6 ft (backs)
		11	2	1 × 8 × 8 ft
Martin house* (2 levels)	1	55		
		21	1	1 × 12 × 21 ft (base)
		4	1	1 × 4 × 6 ft (frame)
		8	1	1 × 10 × 10 ft (roofs)
		3	1	1 × 8 × 4 ft (eaves)
		19	2	1 × 8 × 14 ft (compartment frames)

* Three 8-ft pieces of corner molding are also needed for the martin house.

Therefore, time allotted for data collection will largely determine the cost of a nest box program after its initiation. Manpower estimates for maintenance include the time needed for box repairs and travel to and from nest box sites.

CAUTIONS AND LIMITATIONS

Predation

The rate of predation varies among sites and geographic regions. Fiedler (1974) reported only 12.8% depredation of bluebird boxes in Minnesota, whereas Laskey (1939) found average predation losses of approximately 25% on unguarded boxes in Tennessee, and Kibler (1969) attributed predators with 33% of bluebird losses in New York.

Predators. The chief predators of songbird nest boxes are raccoons and snakes, but others include the black bear (*Ursus americanus*), red squirrel, Virginia opossum, and birds such as house wrens and American kestrels. Jays (*Cyanocitta* spp.), grackles (*Quiscalus* spp.), magpies (*Pica* spp.), and crows (*Corvus* spp.) occasionally destroy eggs and young of other species but seldom interfere with nests inside boxes (Kalmbach and McAtee 1969).

Nest boxes are vulnerable to raccoon depredation because of the raccoon's ability to climb almost any support and reach inside a box to extract nest contents (Zeleny 1976). Raccoons probably learn to recognize nest boxes as potential food sources because they will inspect empty boxes and repeatedly rob those with nests (Pitts 1976).

Snakes are important nest predators, especially in the southern half of the United States; the chief offenders are rat snakes and racers (*Coluber constrictor*) (Zeleny 1976). Snakes swallow eggs or nestlings whole, and a large one can consume an entire brood of nestlings at one feeding. If found in time, the number of eggs or young consumed will be indicated by the clearly visible lumps on the snake's body. Some nest boxes are repeatedly robbed by snakes (Laskey 1946); Pitts (1976) suggested that fence rows may be effective corridors for rat snake movement because of concealment provided by tall grass along many fence bases.

Remains of small birds have been found in the stomach contents of black bears (Hamilton 1978, Landers et al. 1979), and bear predation on birds in natural cavities has been reported for northern flickers in Colorado (DeWeese and Pillmore 1972) and yellow-bellied sapsuckers in Arizona (Franzreb and Higgins 1975). Black bears damaged nest boxes during a bluebird study in North Carolina, where 14 of the 45 damage events resulted in egg or nestling loss (Tardell and Doerr 1982).

The red squirrel can enter a nest box with an opening 1-1/2-in. in diameter and will gnaw away wood to gain entrance if necessary (Zeleny 1976). It will consume eggs or nestlings and occasionally kill an adult in a nest box raid. Pinkowski (1975) found that nests with eggs offer the greatest opportunity for squirrel predation; unlike raccoons, red squirrels consume the eggs while inside the nest box.

Domestic cats are potential predators of nesting birds. A study of farm cats in Illinois showed that a large percentage of prey items was small birds (Landers et al. 1979), and Fiedler (1974) and Laskey (1942) attributed a high percentage of nest box depredation to domestic cats. Cats usually present a greater threat to birds on the ground (Kibler 1969), but they will raid nests in a manner similar to that of raccoons (Zeleny 1976). Predator guards used to control cats should be high enough to prevent their leaping from the ground to gain a hold above the guards (Kalmbach and McAtee 1969).

Signs of predation. Zeleny (1976) described general indications of predation encountered in bluebird boxes, and the information is applicable to most nesting species. A reliable sign of predation is the disappearance of eggs or nestlings younger than fledging age. A depredated yet intact nest that still contains unbroken eggs or live nestlings should be left undisturbed, but precautions are required to prevent further predation. If both living and dead nestlings are present, the dead ones should be removed. However, if all eggs or nestlings have been destroyed, the remaining contents of the box should be discarded and consideration given to relocating the box or installing a predator guard.

Specific signs may indicate the source of predation. Raccoons usually leave a badly disrupted nest with no eggs or nestlings. Part of the nest may have been removed, and remains of nestlings or adults may be on the ground near the box (Zeleny 1976). Eggs may also roll underneath nest material if the raccoon could not reach them. Characteristic signs of black bear damage are claw and teeth marks and partial destruction of nest boxes. Tardell and Doerr (1982) found the front and side pieces pulled away from the back, which remained attached to the box support in each of 45 damage events. A good sign of snake predation is a clean intact nest from which eggs or nestlings have disappeared, and gnawing around a box entrance probably indicates red squirrel predation (Zeleny 1976).

Predator control. Various methods may be used to control predatory animals. Several types of sheet metal guards have been successful (Zeleny 1976), as have boxes placed on metal pipes (Pitts 1976), smooth metal fence posts, and angle iron posts (Zeleny 1976). A heavy coating of automobile grease has been used on smooth posts (Pinkowski 1975); however, it must be applied several times during the nesting season to prevent hardening, which allows easier access to the nest than does an untreated pole (Zeleny 1976). Smooth metal supports and/or the conical metal guards shown in Figure 11 are generally recommended, but these devices are not 100% effective in controlling predators.

Abandonment

When a nest has been abandoned, the chances of saving the eggs are greatest if incubation has not begun (Zeleny 1976). The eggs usually remain viable for a few days and may be successfully incubated in another nest with incomplete or just completed clutches. Artificial incubation is not recommended because it is an involved procedure classified as artificial propagation of wildlife and requires a permit from the US Fish and Wildlife Service. Abandonment of nestlings usually indicates the death of both adults. If nestlings are strong enough to raise their heads and open their mouths, they may be transferred to another box with nestlings of approximately the same age. Only a few eggs or nestlings should be placed in an orphan nest.

Care should be taken in determining whether a nest has been abandoned. Nestlings should not be considered abandoned unless one can be sure they have not been fed for a period of at least 4 daylight hours; observation at a distance of 50 ft may be required if there is any doubt. If nestlings are conspicuously limp, cold, and barely able to move, it can be assumed that they have been abandoned.

Interspecific Competition

Competition may be expected from nontarget species that use boxes of approximately the same size in the same habitat. Boxes erected for bluebirds have received heavy use by tree swallows (Miller 1970, Rustad 1972b) and are frequently used by violet-green swallows (Brawn and Balda 1983), ash-throated flycatchers (Zeleny 1976), Carolina wrens (Zeleny 1971), Bewick's wrens (Zeleny 1976), chickadees (Hurst 1983), titmice (Willner et al. 1983), and nuthatches (Gary and Morris 1980). House wrens not only compete with other species for nest boxes but also destroy their eggs and young (Henderson 1984). Stauffer and Best (1982) found that great crested flycatchers, red-headed woodpeckers, and red-bellied woodpeckers chose similar natural nest sites; this suggests that competition among these species might be anticipated because they would use boxes of approximately the same size for nesting.

Interspecific competition can be avoided or greatly reduced by providing sufficient nest boxes in the preferred habitats of the competing species. For example, wren houses can be located in brushy areas of backyard or forest edges to attract wrens away from boxes intended for species that prefer more open habitats; wrens tend to use boxes where trees or shrubs are near the entrance of the box (Willner et al. 1983). Bluebird boxes, in particular, should not be placed near shrubs or thickets but rather in areas of low vegetation such as mowed or grazed pastures with scattered trees (Zeleny 1976). To reduce competition between tree swallows and bluebirds, boxes may be provided for swallows near bodies of water (Rustad 1972b). Bluebirds tend to use boxes where the height of the herbaceous vegetation is less than at boxes used by house wrens and tree swallows (Willner et al. 1983).

In areas with large populations of house sparrows and/or starlings, boxes located in open habitat should be placed at least 1300 ft from human habitations and farm buildings, or other places where animals are fed (Munro and Rounds 1985). House sparrows compete with most cavity nesters except those that can use a 1-1/4-in.-diam entrance and readily usurp houses intended for native birds (Fig. 12).

Nest boxes located in woodland habitats are usually safe from starlings and house sparrows (Zeleny 1976), but starlings have penetrated into wilder areas in recent years and compete with woodpeckers for natural cavities (Short 1979). Troetschler's (1976) studies of the acorn woodpecker (*Melanerpes formicivorus*) in western North America indicated a substantial impact of starlings on that species. Starlings will nest along streambanks, woodland edges, and semi-open areas with scattered trees (Zeleny 1976). Therefore, it is important to consider the potential competition from starlings when locating boxes for woodland species, as well as for species that nest in the open, and to observe the critical entrance hole dimensions in nest box construction.

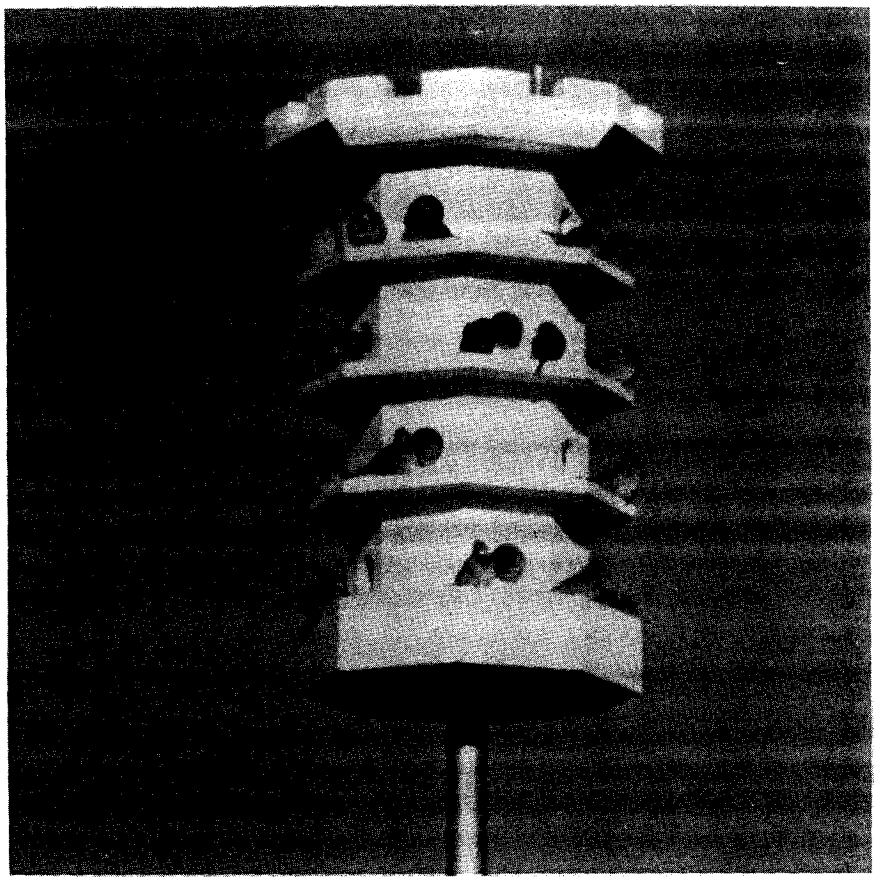


Figure 12. House sparrows readily usurp houses intended for colonial nesters such as purple martins

Vandalism

Some degree of vandalism may be encountered in any nest box program (Krug 1941, Petersen 1969, McComb et al. 1987). Boxes may be dislodged, damaged, totally destroyed, or even disappear; however, destruction of nest contents may occur with no damage to boxes (Zeleny 1976). A sign of human predation is the removal of a roof or box side and the simultaneous disappearance of eggs, nestlings, or an entire nest.

Human interference can be minimized by informing the public about a nest box program and creating support for it through schools, youth organizations, and social groups (Zeleny 1976). Boxes can be made inconspicuous by constructing them from old or darkened wood so they will blend with the environment (Krug 1941). Attaching a small identification plate to each box may also serve as a deterrent because nest disruption is a violation of Federal and state laws (Kibler 1969).

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